The State of the Climate, Energy & Efficiency

The Good, the Scary, the Bad and the Ugly

David Gallaher National Snow and Ice Data Center

Presented by

NSIDC National Snow and Ice Data Center
Supporting Cryospheric Research Since 1976

Affiliations and Sponsorships

RMH GROUP FEMP Federal Energy Management Program NASA CIRES NSF

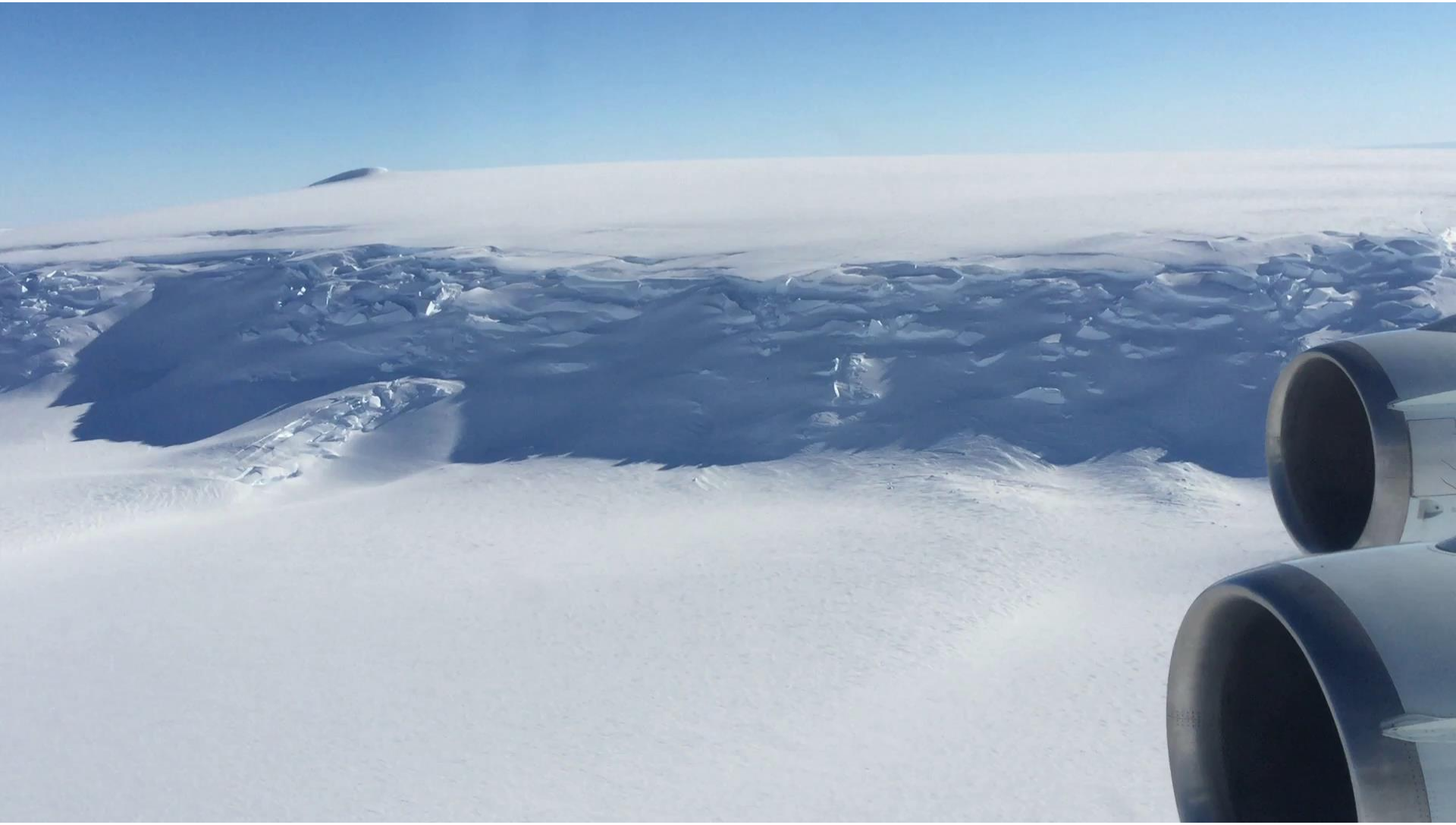
First: A brief on the NASA operation Ice Bridge Mission over Antarctica

A Good Deal of Flying to Collect Climate Data

Each Mission was 13 hours from Punta Arenas, Chile
to Objectives over Antarctica

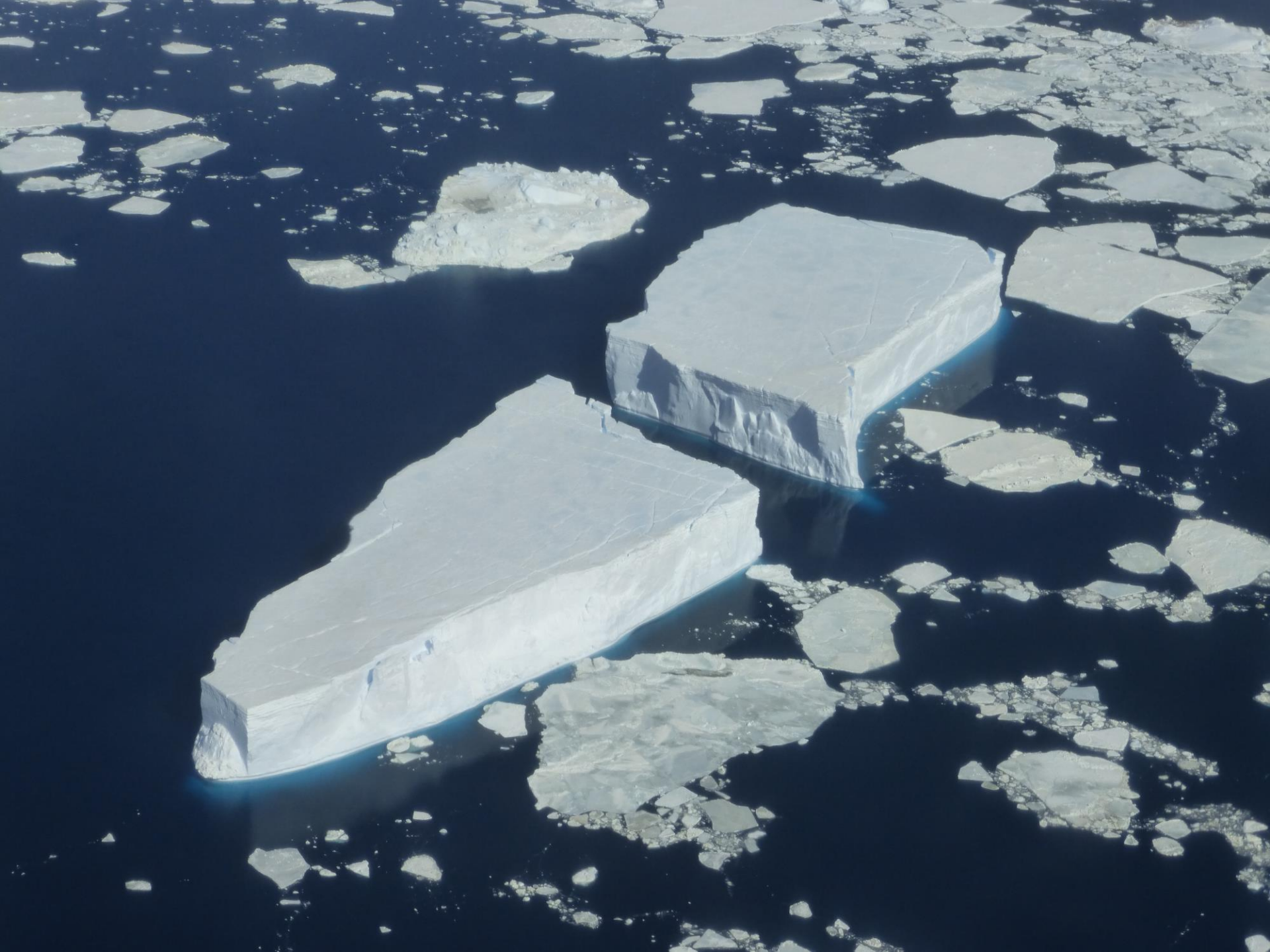
Using a fleet of research aircraft, NASA’s Operation IceBridge images Earth's polar ice to better understand connections between polar regions and the global climate system.

I flew 40,000 miles over western Antarctica with a miniaturized microwave sensor designed for a satellite launch



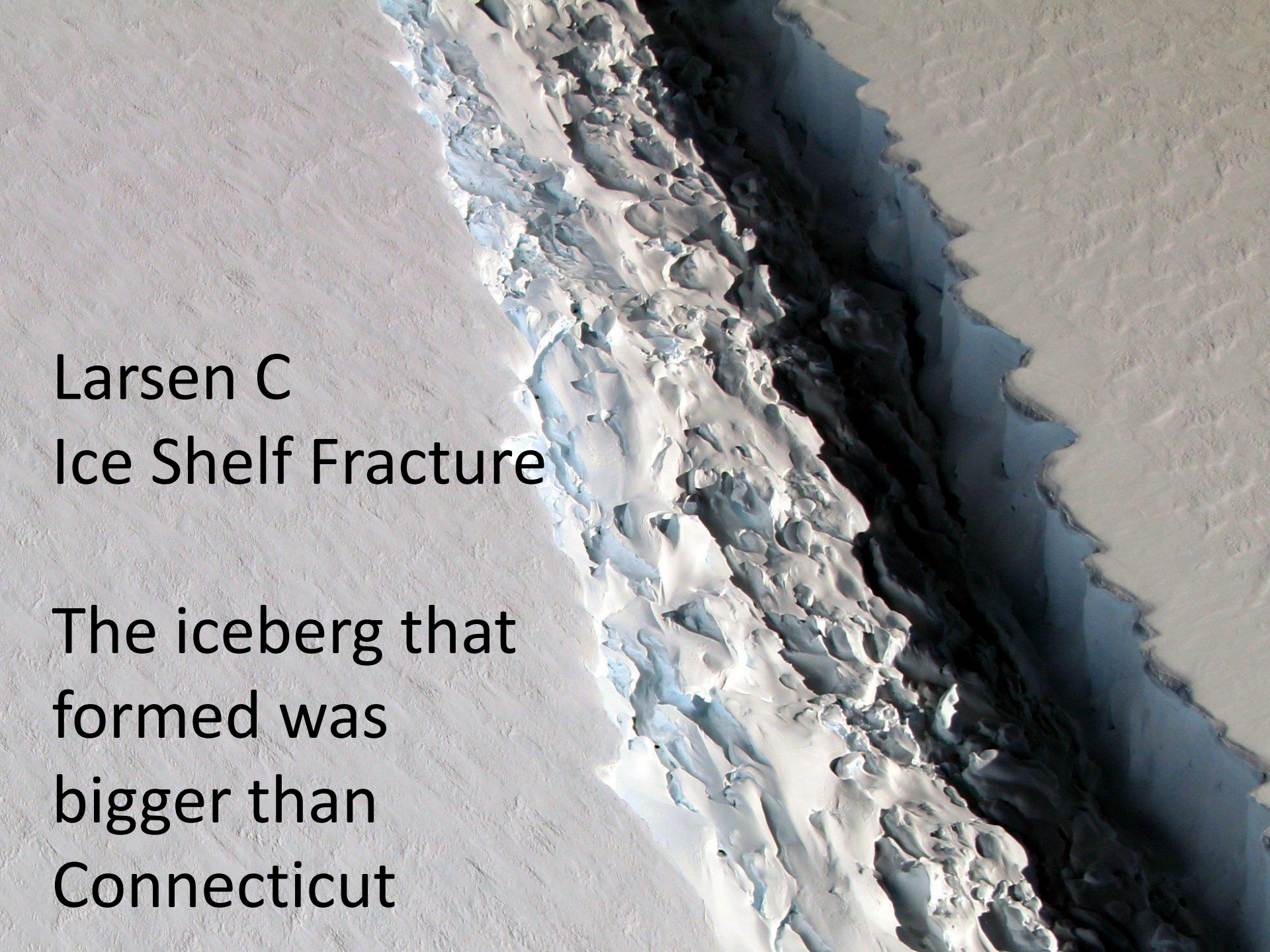
The ice cliffs here are about 3000’ thick

Flying over the Shackleton Range




Over the last few years we are seeing much more much more open water than we had ever seen at this time of year.

Flying over sea ice at 700 feet

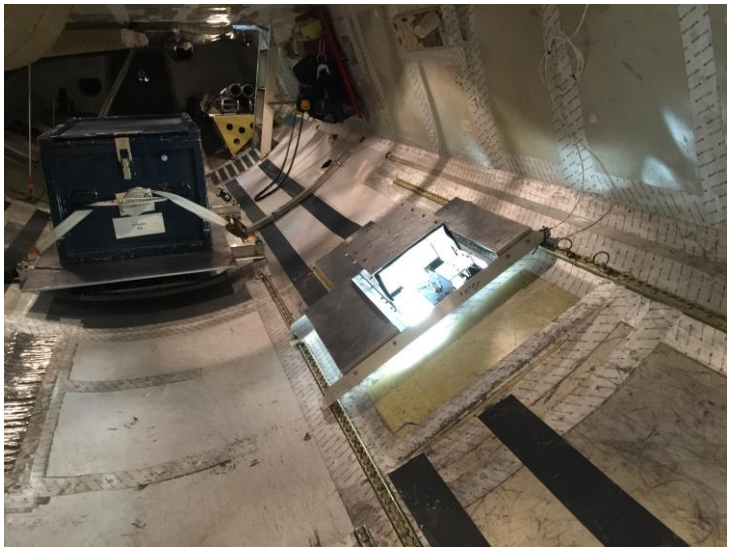


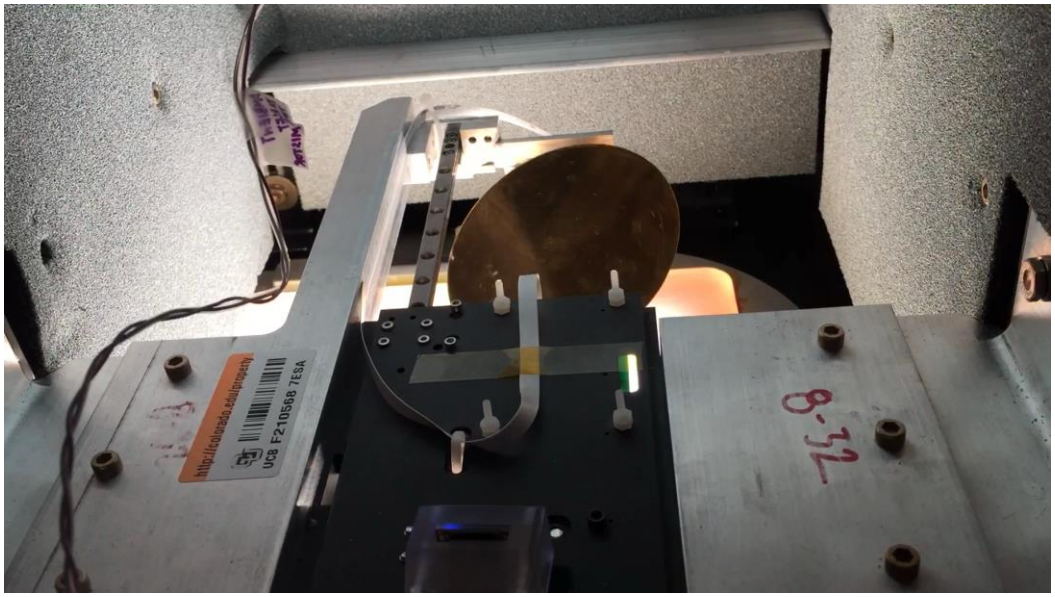
Larsen C
Ice Shelf Fracture

The iceberg that formed was bigger than Connecticut

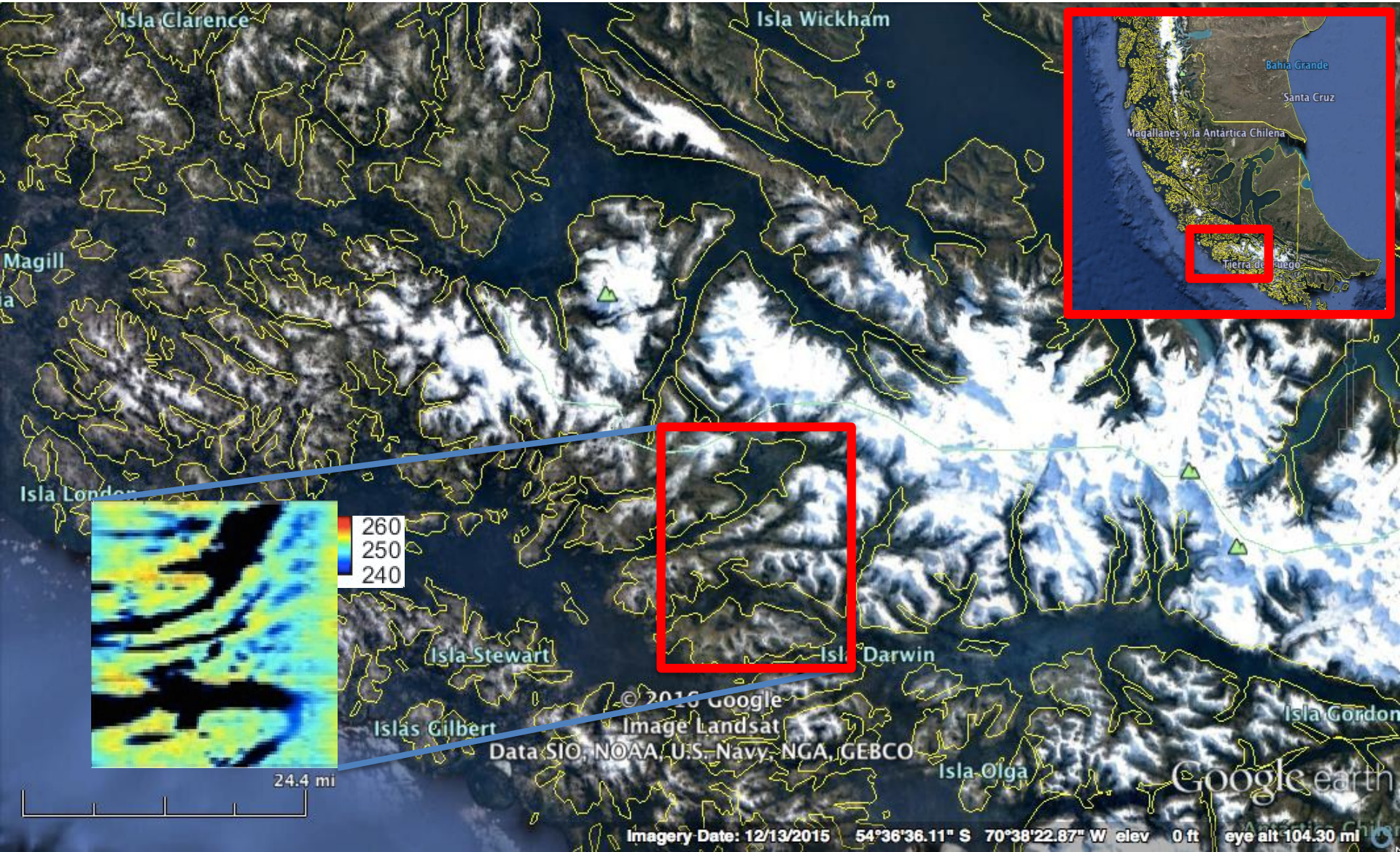
Why was I there?

- To test & collect data from a miniaturized Passive Microwave sensor
- This sensor was launched into orbit in April 19th of this year
- Orbital Micro System (OMS) and the University of Colorado (as a partial owner) will build a commercial fleet of 40 of these satellites
- This will enable global weather updates anywhere on Earth every 15 minutes for climate, aviation, agriculture, storm disasters etc .
- The **5PB** of data collected annually will be managed by the OMS owned International Center for Earth Data (ICED) and the University of Edinburgh, Scotland



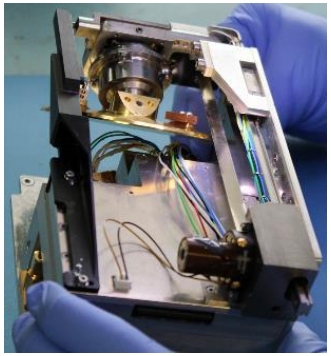


Sensor Temperature-Brightness in °K 10/26/16 over Terra del Fuego, Chile, at 118.750±5.0 GHz

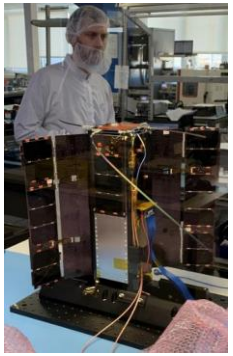


OMS/IOD-GEM-1

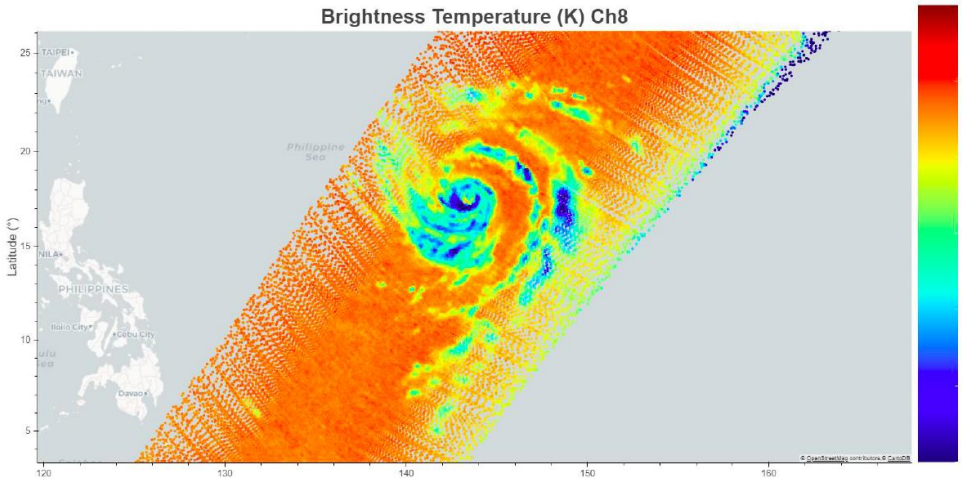
Toward Collecting Global Atmospheric Climate Data every 15 minutes



Payload Sensor

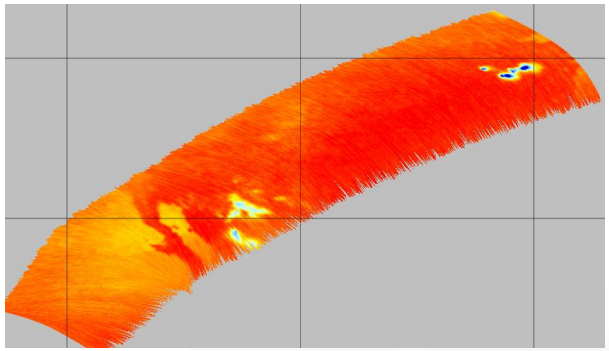


Satellite



Typhoon Hagiblis 10/8/19

Launch off Space Station 6/28/19

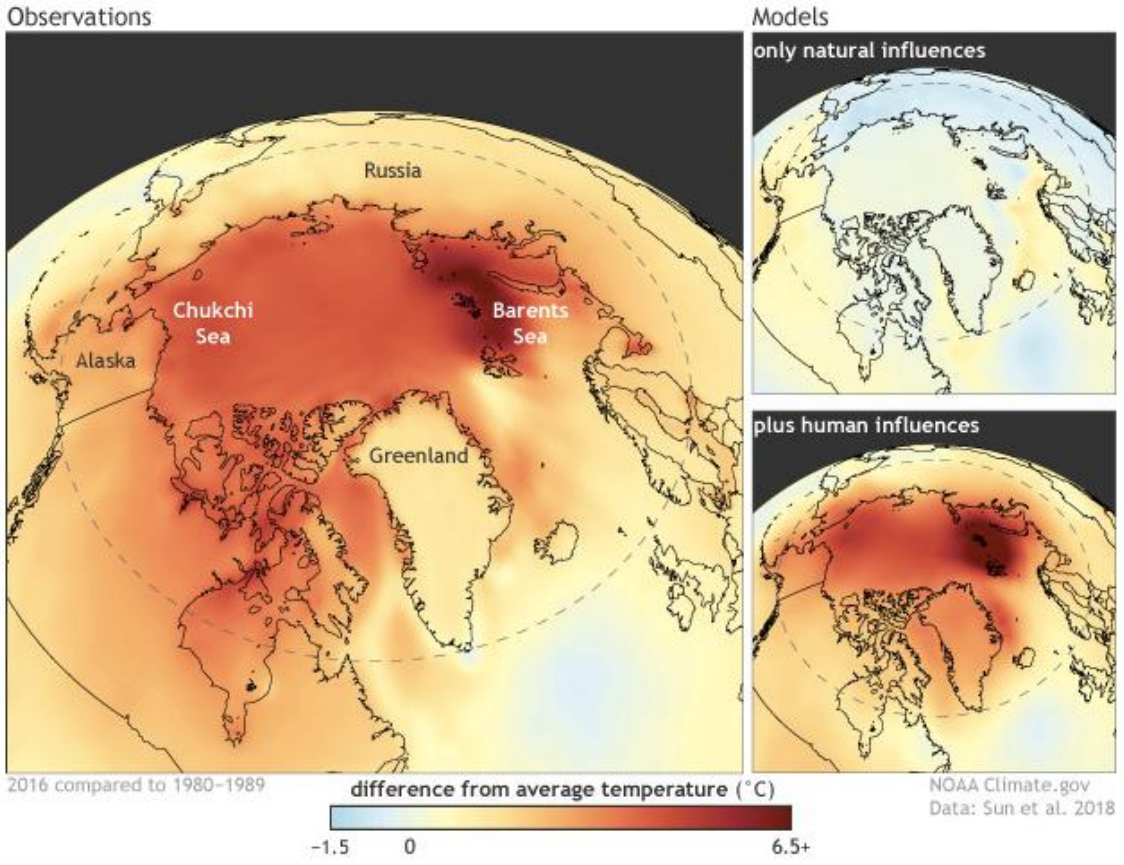


First Light 7/19/19

Now for the Scary Stuff

- The climate is changing
- There are real impacts
- Earths coldest years were 90 years ago
- The coldest year on record occurred in 1904
- Warming is happening fastest in the Arctic
- It's happening now, not 10 years from now or 2050
- It's us….
- What do we do about it.

2018 Arctic Winter heat would have been virtually impossible without global warming. Without the Oceans absorbing most of the heat, the temperatures would have been 60^{o} F higher



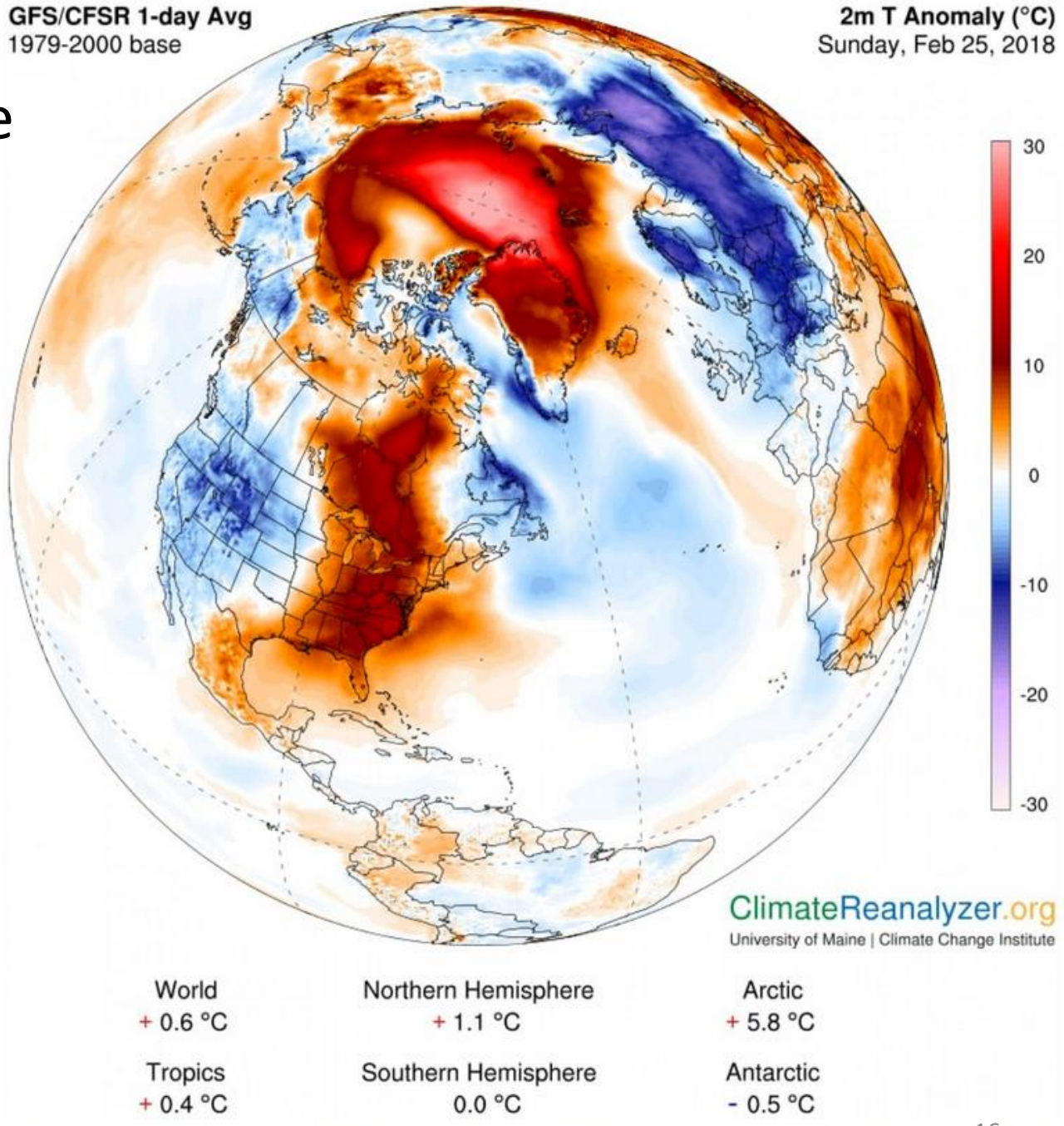
Changes in the Arctic Winter 2016 & 2018

- As the Arctic slipped into the half-darkness of autumn last year, it seemed to enter the Twilight Zone. In the span of a few months, all manner of strange things happened.
- The cap of sea ice covering the Arctic Ocean started to shrink when it should have been growing. Temperatures at the North Pole soared almost 40°F above normal and the ice in Northern Greenland to the Pole started to melt

2018: North Pole surges above freezing in the dead of winter

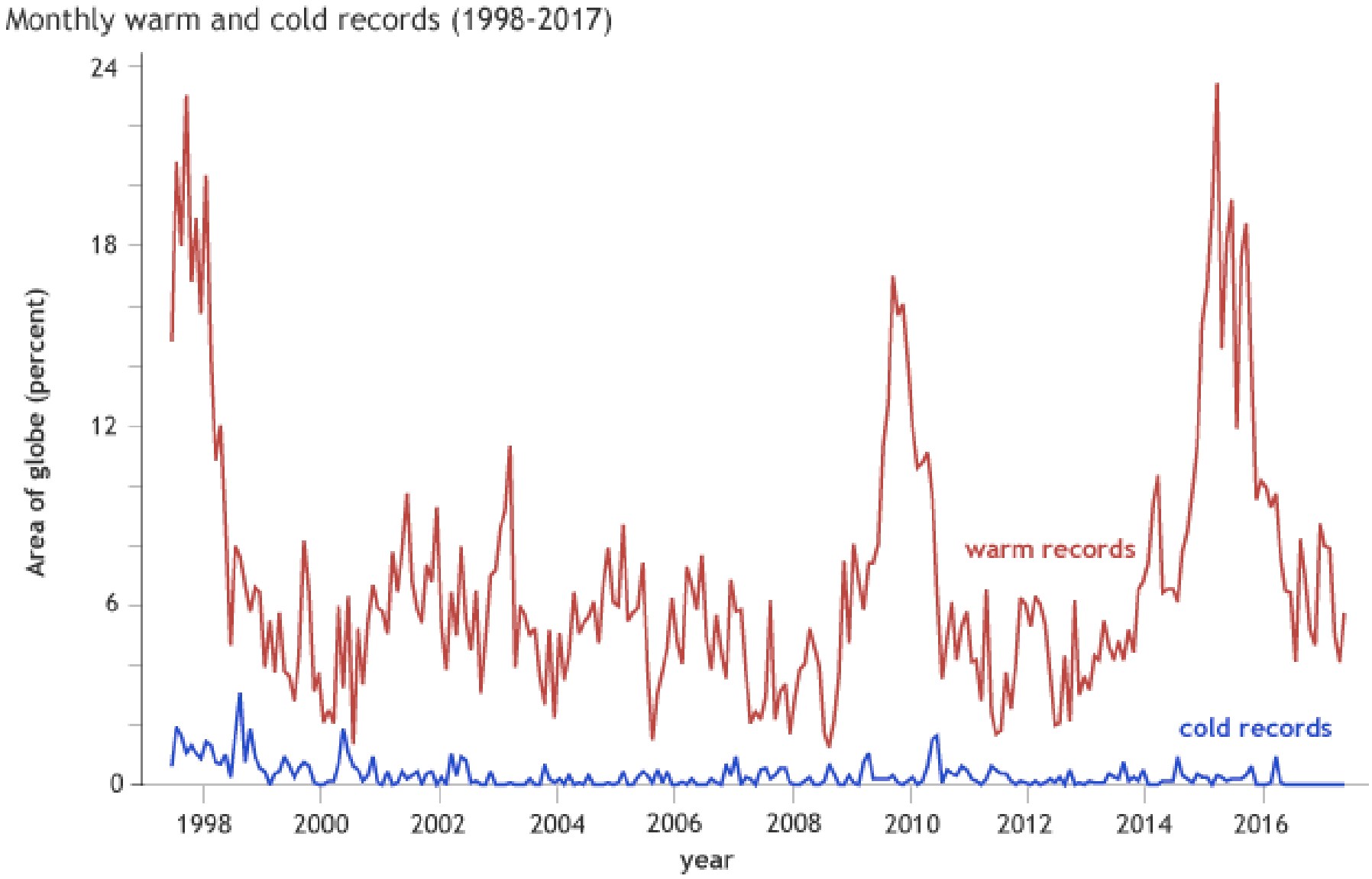
It is dark 24/7 that time of year

17 of the 18 hottest years on record have occurred since 2000

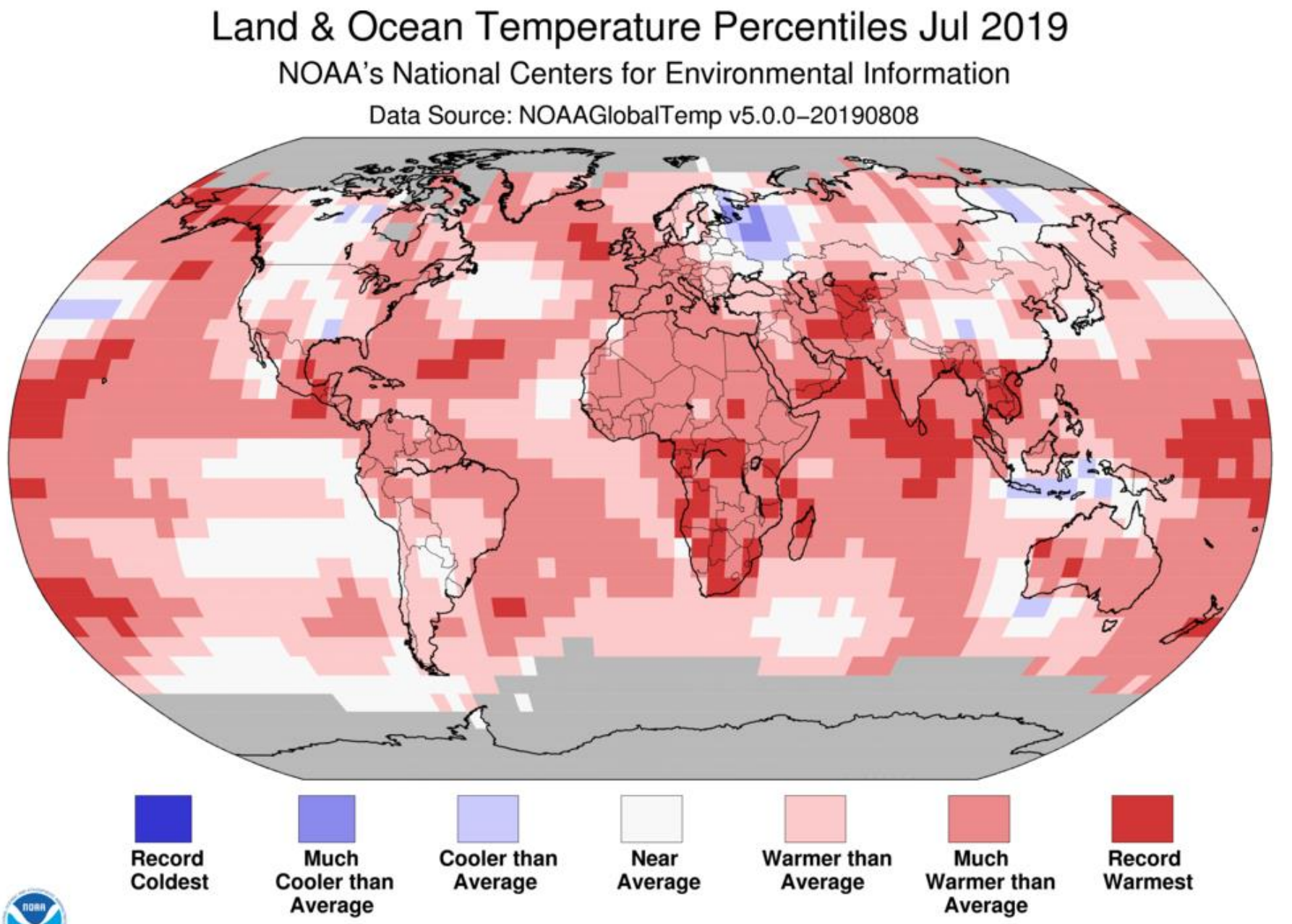


GFS model analysis of temperature difference from normal (in Celsius) on Sunday over the Arctic. The temperature is above freezing at the North Pole. (University of Maine Climate Re-analyzer)

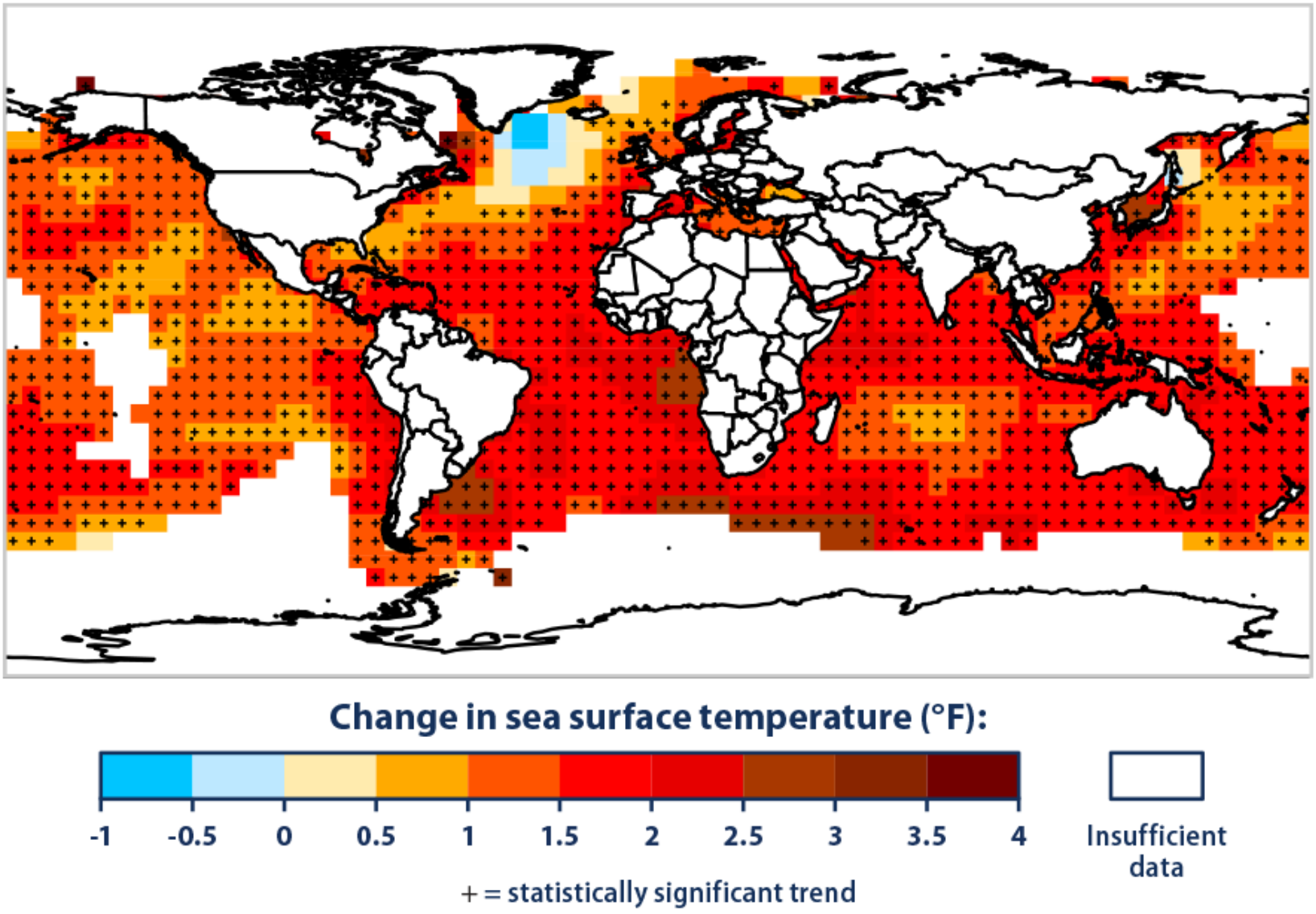
Temperature Records



Hottest Month Ever Recorded

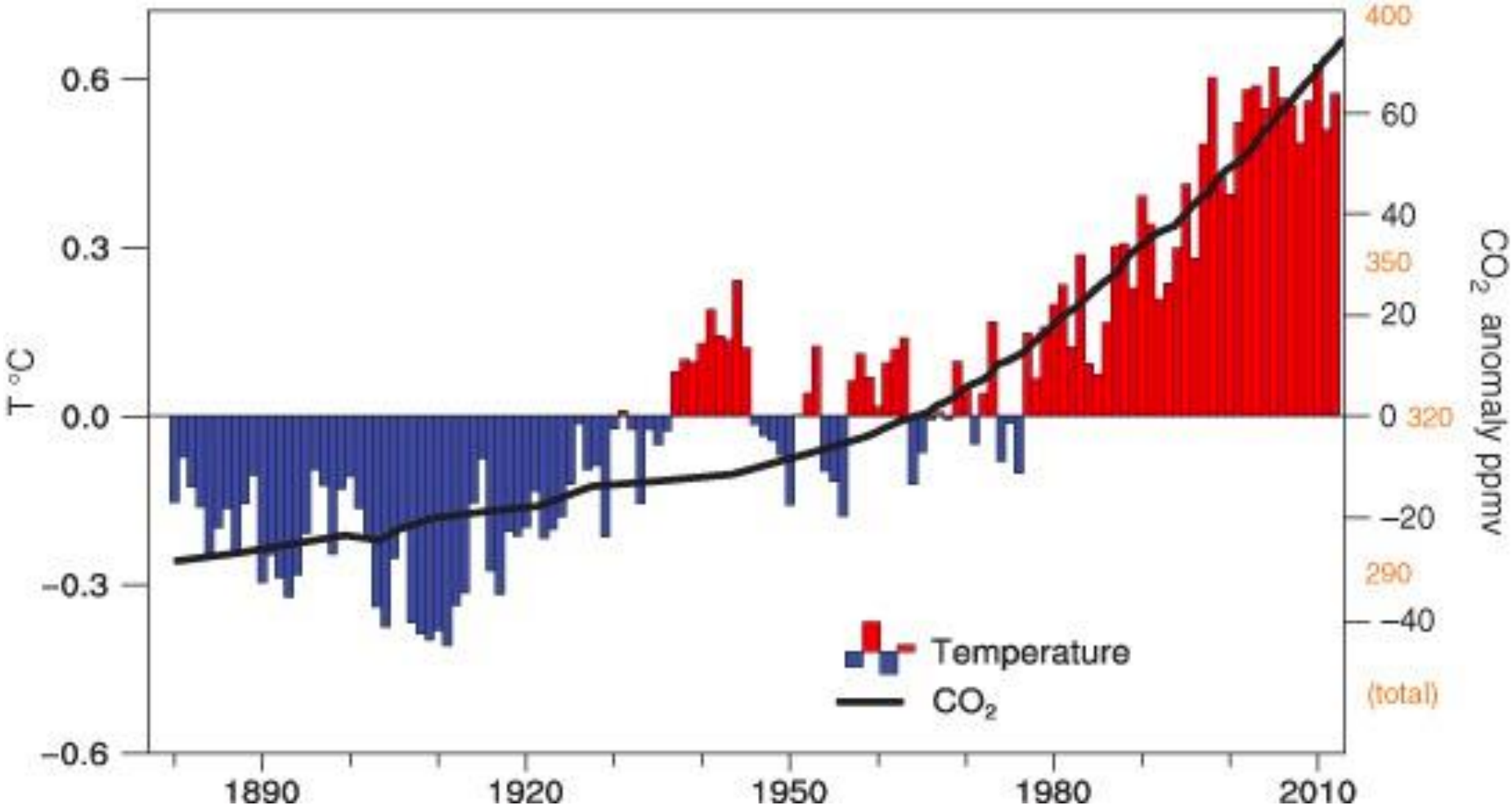


Change in Sea Surface Temperature 1901-2015



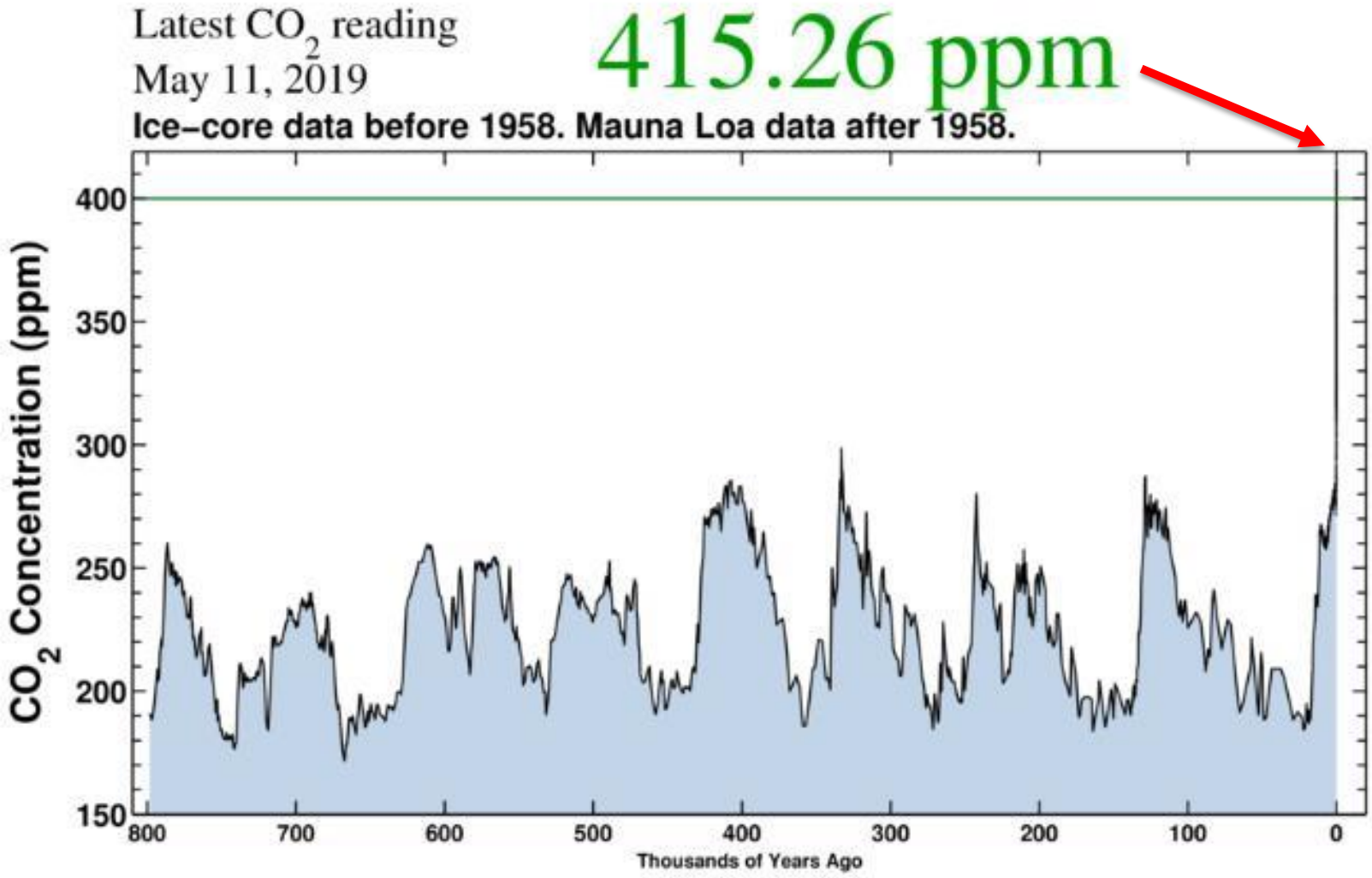
Source: US EPA

Annual Global Mean Surface Temperatures

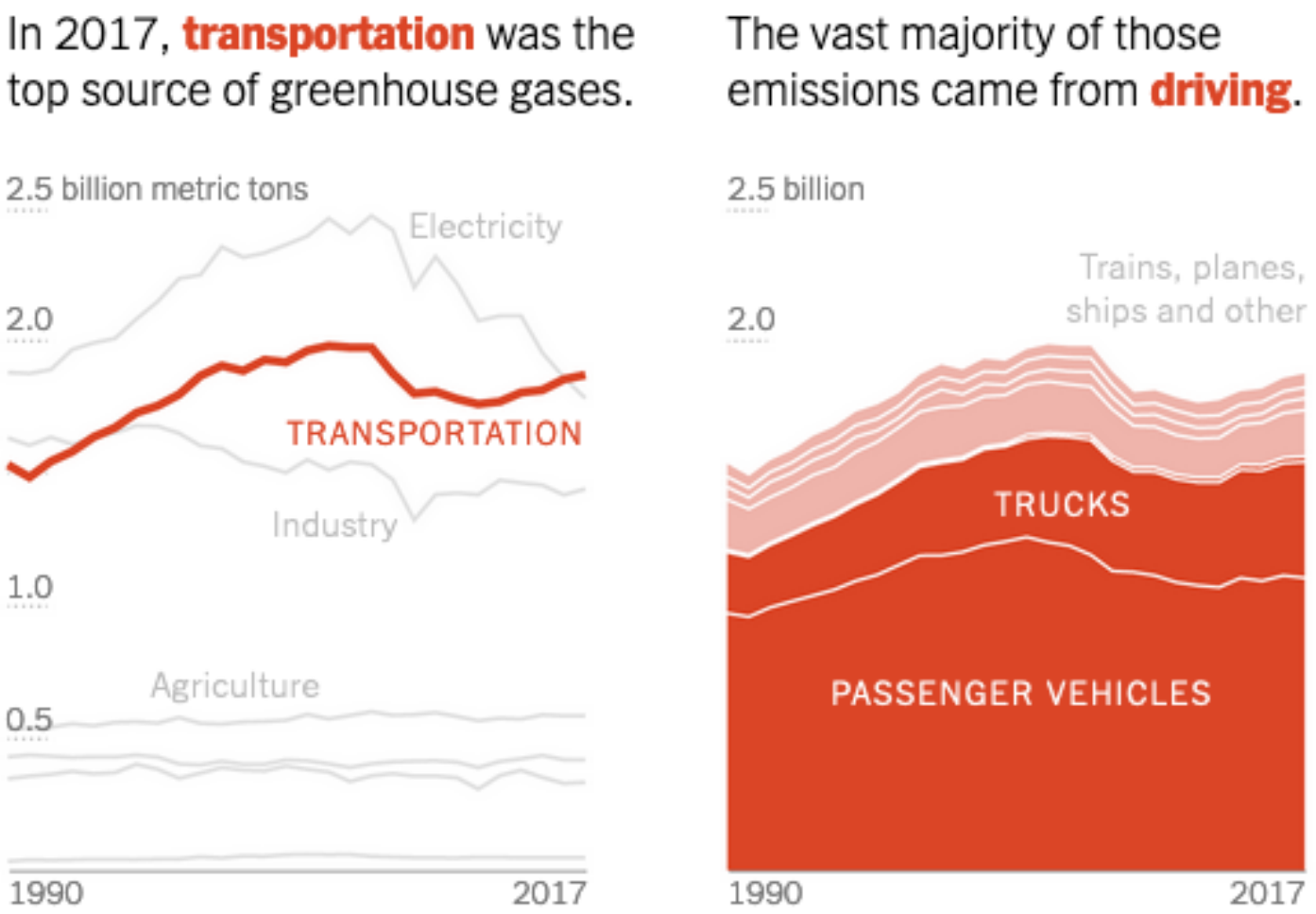


NOAA

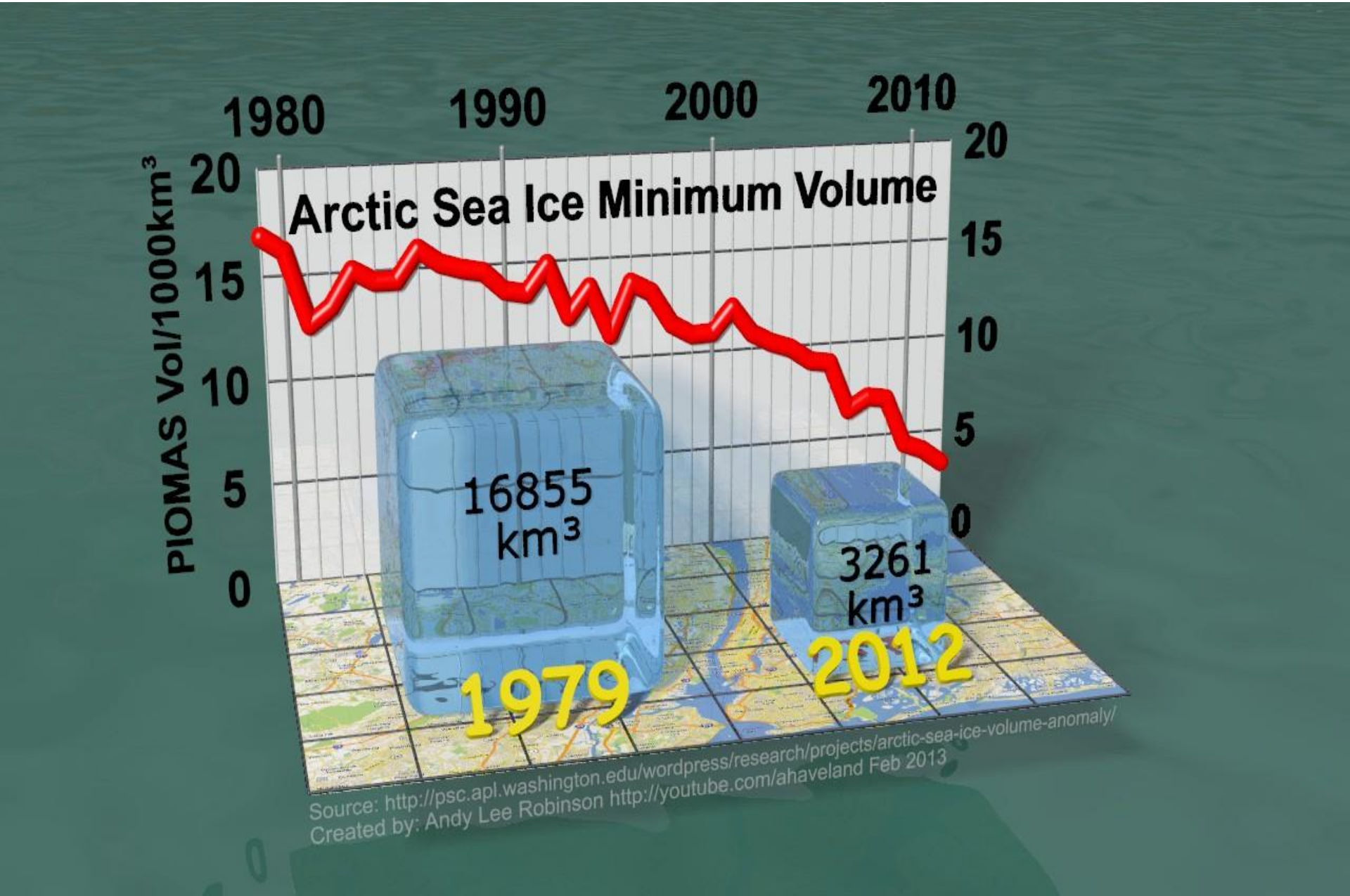
CO_2 Readings over the last 800,000 years



Sources of U.S. CO_2 Emissions



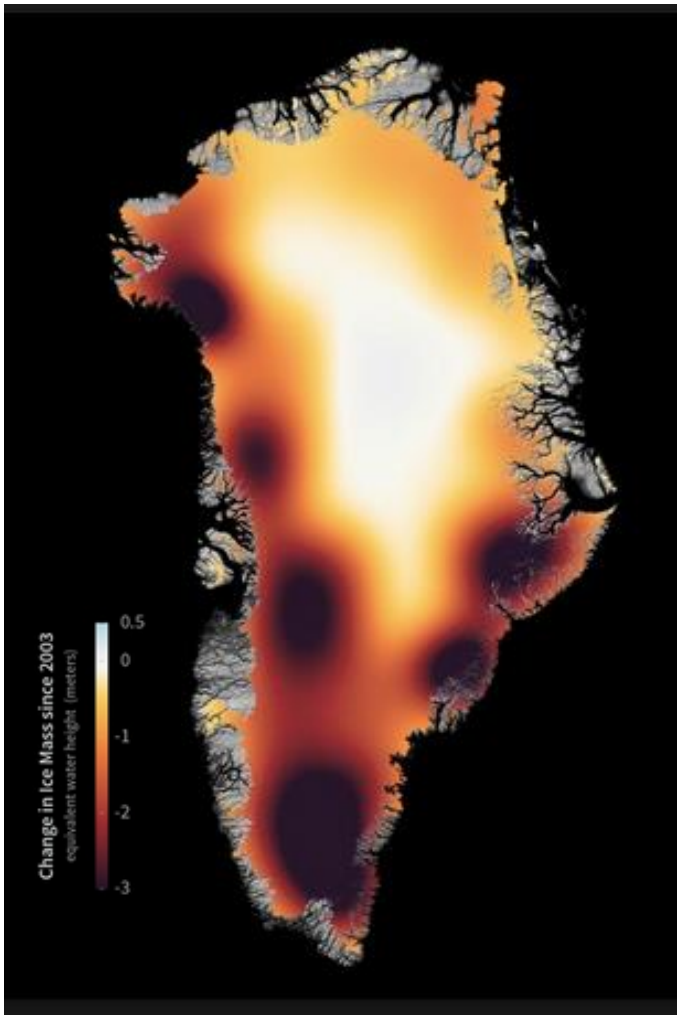
Charts show the carbon dioxide equivalent of greenhouse gas emissions.
Source: Environmental Protection Agency

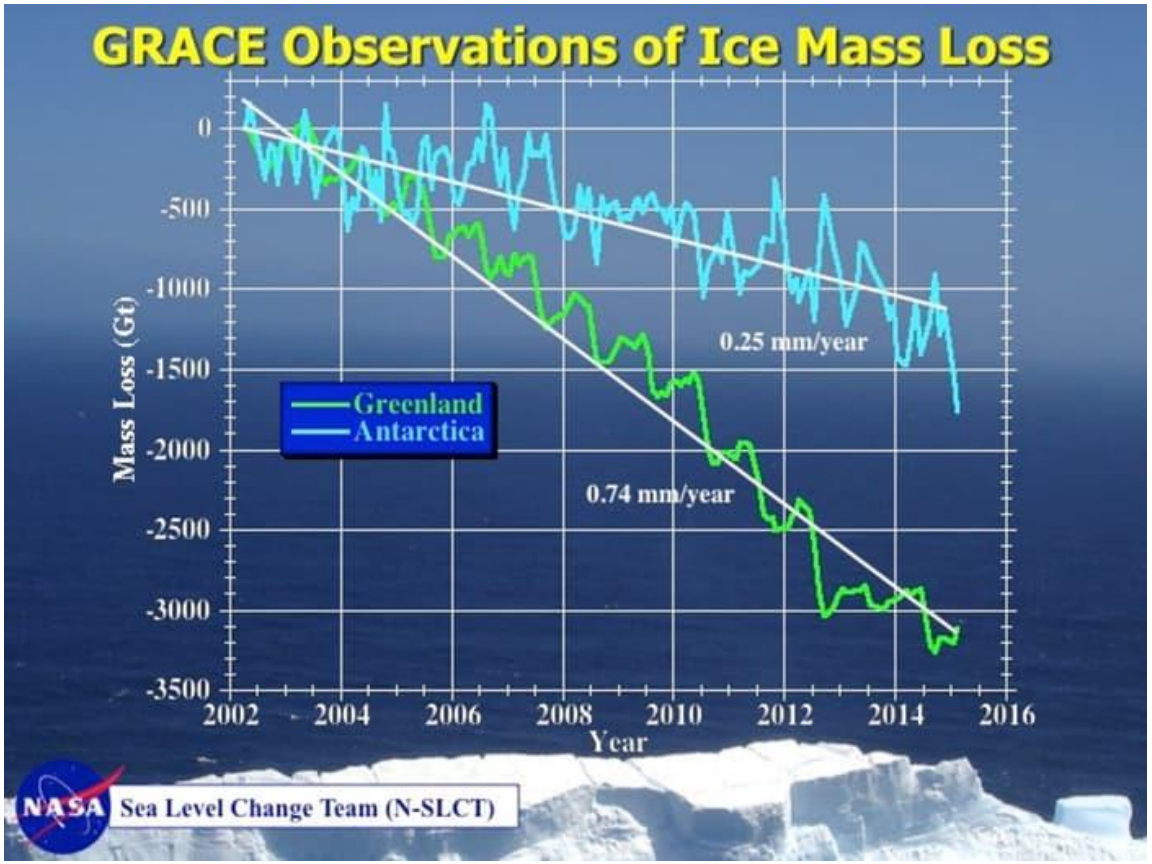

1980
1990
2000
2010
Arctic Sea Ice Minimum Volume
PIOMAS Vol/1000km³
20
15
10
5
0
16855
km³
3261
km³
1979
2012
Source: http://psc.apl.washington.edu/wordpress/research/projects/arctic-sea-ice-volume-anomaly/
Created by: Andy Lee Robinson http://youtube.com/ahaveland Feb 2013

Ice Volume losses

From NASA GRACE Gravity Mission

Greenland

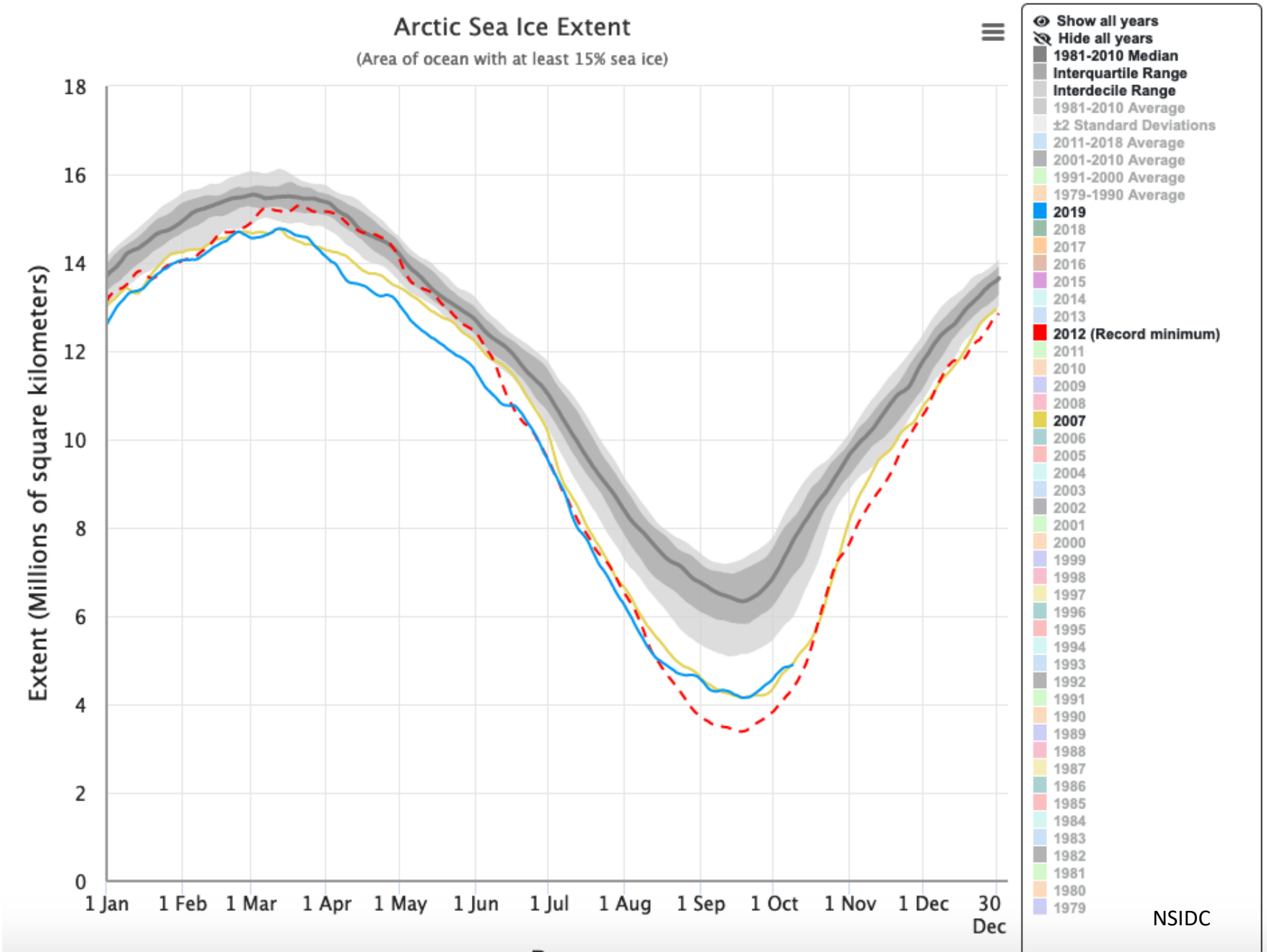


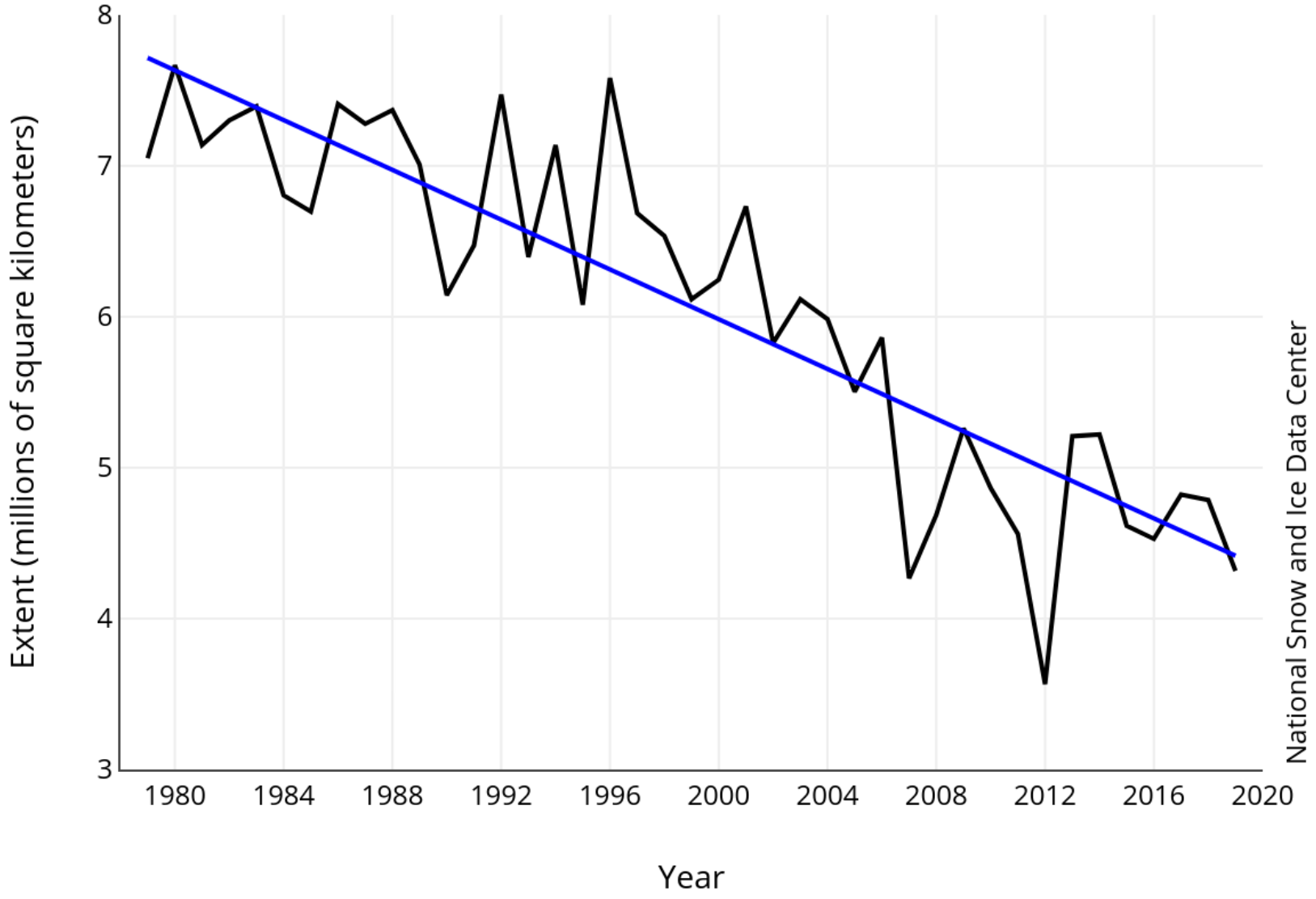


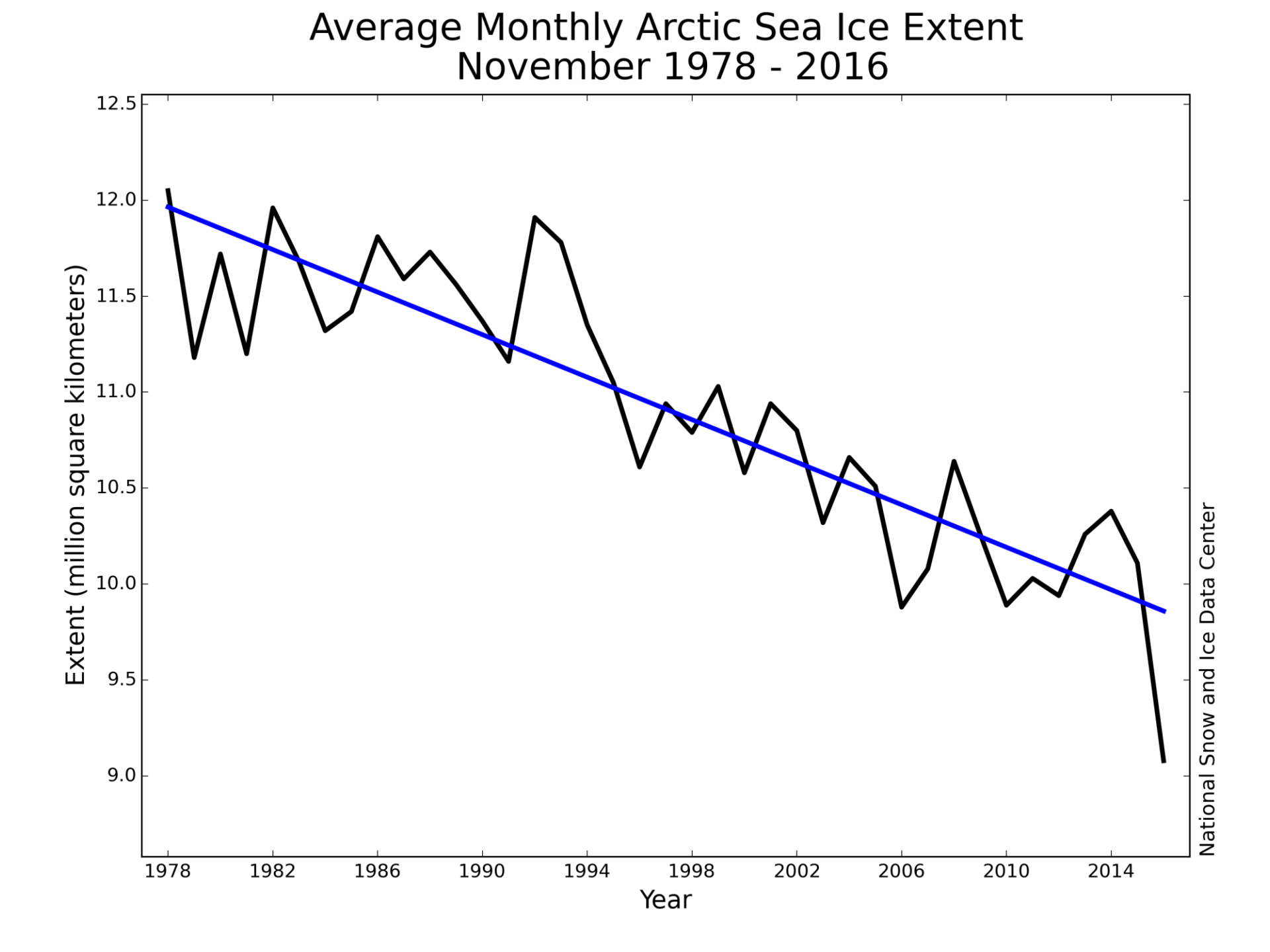
- **Contributes to sea level rise**

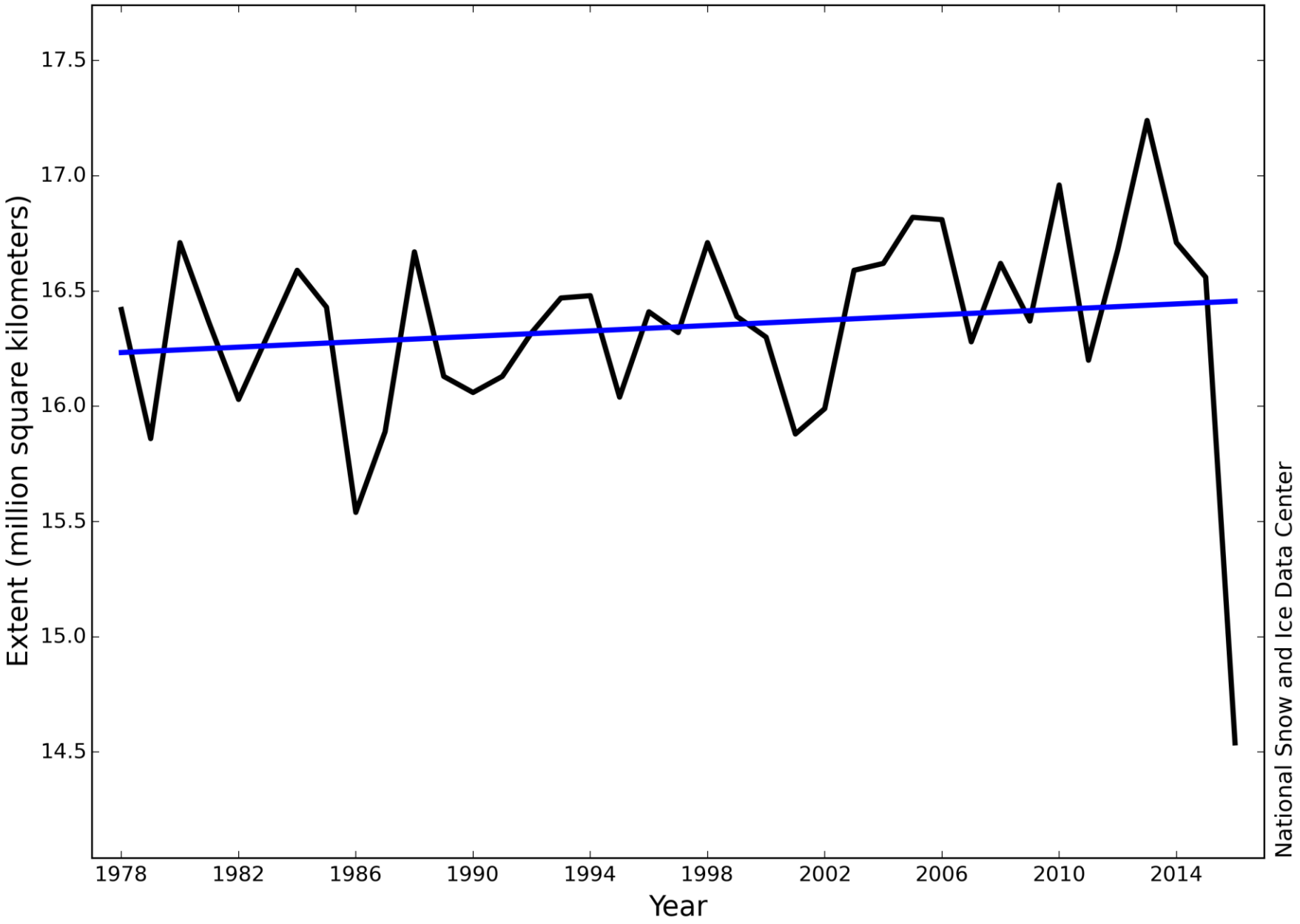
J. Wahr, U. Colorado

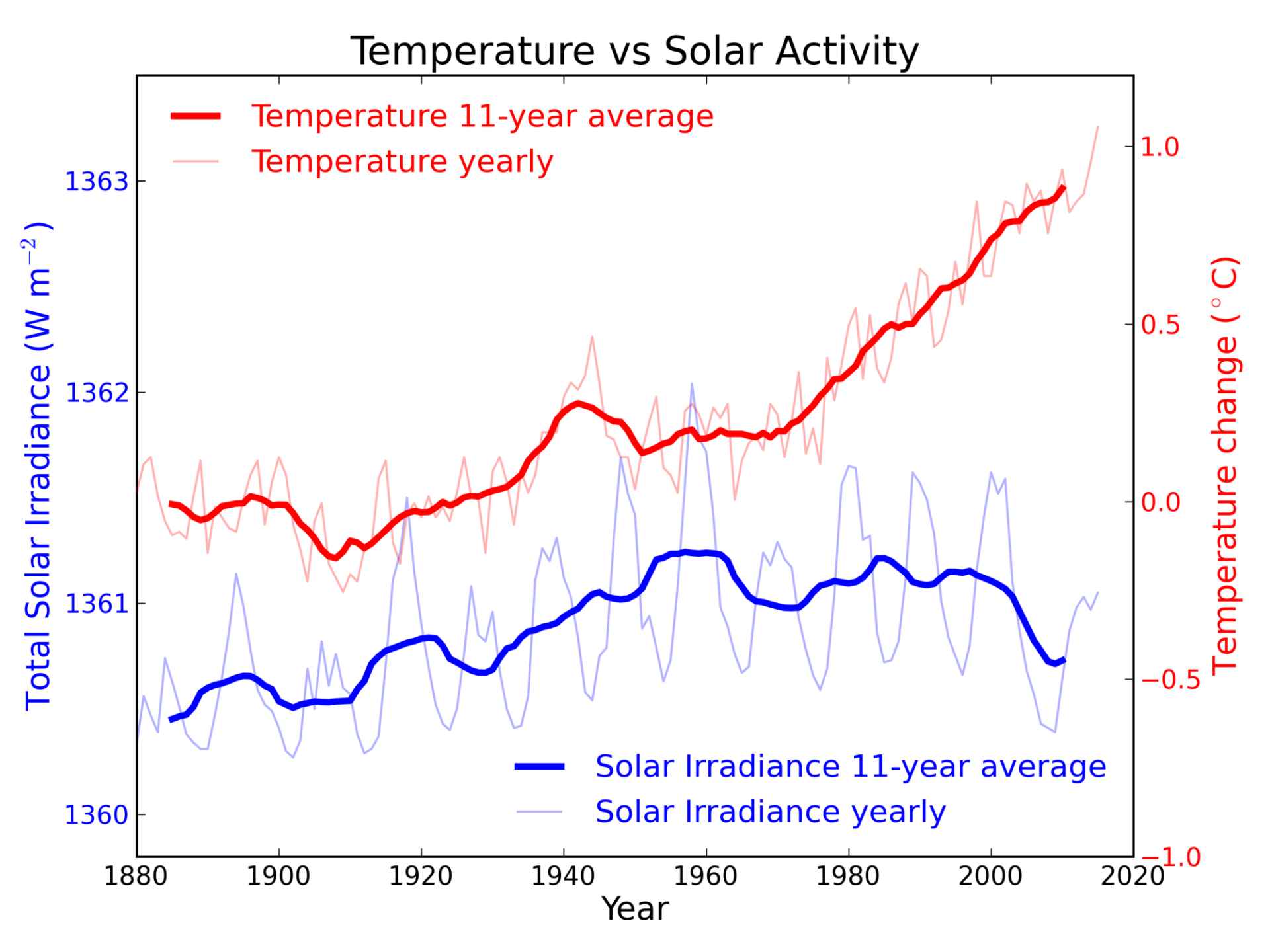
Arctic Sea Ice Extent with 1981-2010 Median and Lowest 3 Years, 2012, 2007, 2019




Average Monthly Arctic Sea Ice Extent
September 1979 - 2019
Extent (millions of square kilometers)
8
7
6
5
4
3
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016
2020
Year
National Snow and Ice Data Center


Average Monthly Arctic Sea Ice Extent
November 1978 - 2016
Extent (million square kilometers)
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year
National Snow and Ice Data Center


Average Monthly Antarctic Sea Ice Extent
November 1978 - 2016
Extent (million square kilometers)
17.5
17.0
16.5
16.0
15.5
15.0
14.5
1978
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year
National Snow and Ice Data Center


Temperature vs Solar Activity
Temperature 11-year average
Temperature yearly
Solar Irradiance 11-year average
Solar Irradiance yearly
Total Solar Irradiance (W m^{-2})
Temperature change (°C)
Year
1363
1362
1361
1360
1.0
0.5
0.0
−0.5
−1.0
1880
1900
1920
1940
1960
1980
2000
2020

Explaining the Difference Between Weather and Climate

Weather forecast is:
Predicting when one specific leaf will fall off the tree.

Climate forecast is:
Predicting when all the leaves will fall off the tree.

Historic science data improves both forecast

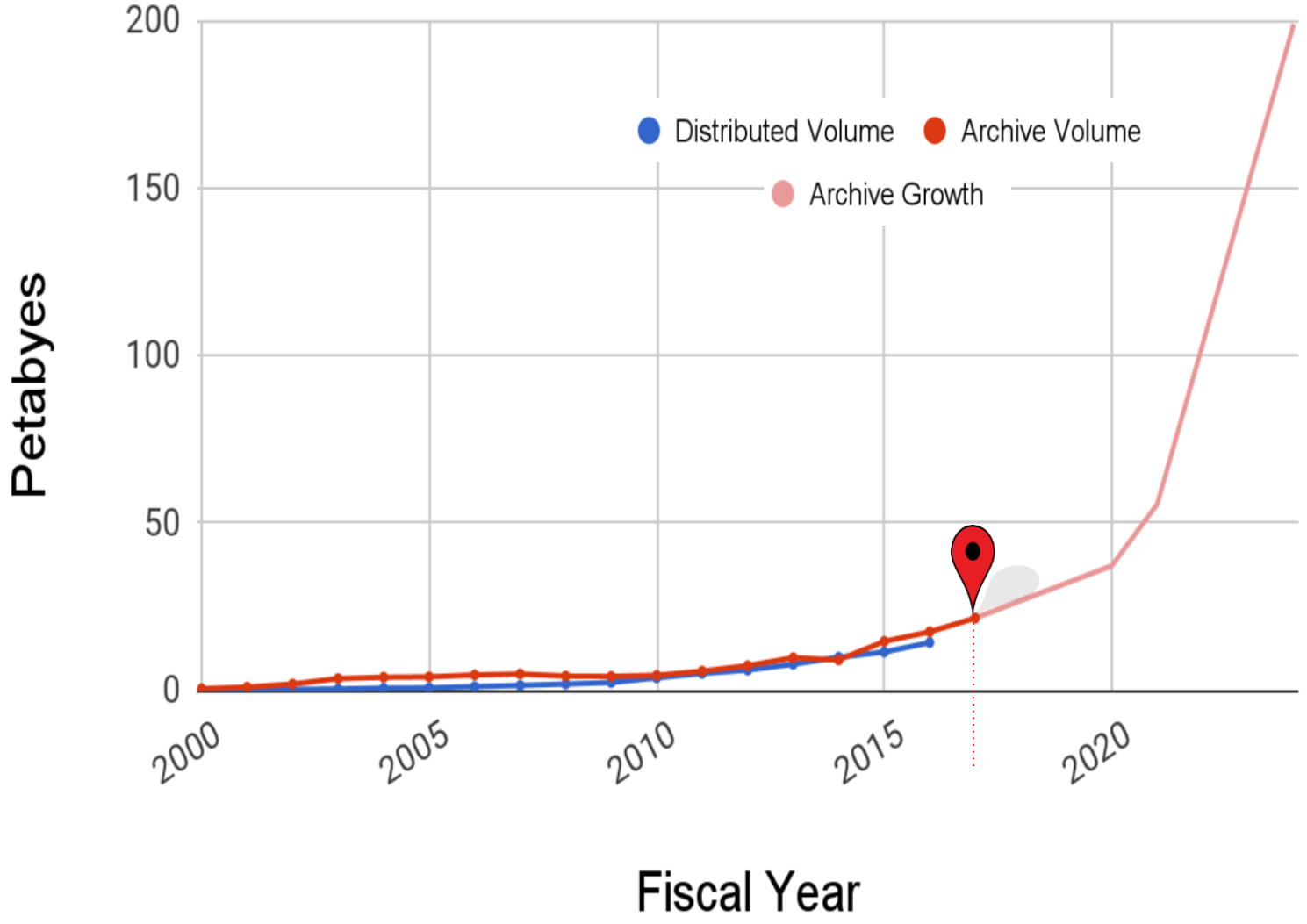
So what is NASA doing about Climate Change?

Some degree of global change is irreversible. NASA's role is to provide data needed to understand and model Earth's climate, which can help policymakers make informed decisions on steps to mitigate global change and its effects.

We need to **Monitor** (study what is happening); **Mitigate** (reduce emissions to reduce future climate change) and **Adapt** (react to current changes and preparing society for changes that are sure to occur no matter what we do).

The best way to mitigate climate change is to become more **efficient** with the energy while cutting costs as well.

NASA's estimate on their Earth monitoring data volume

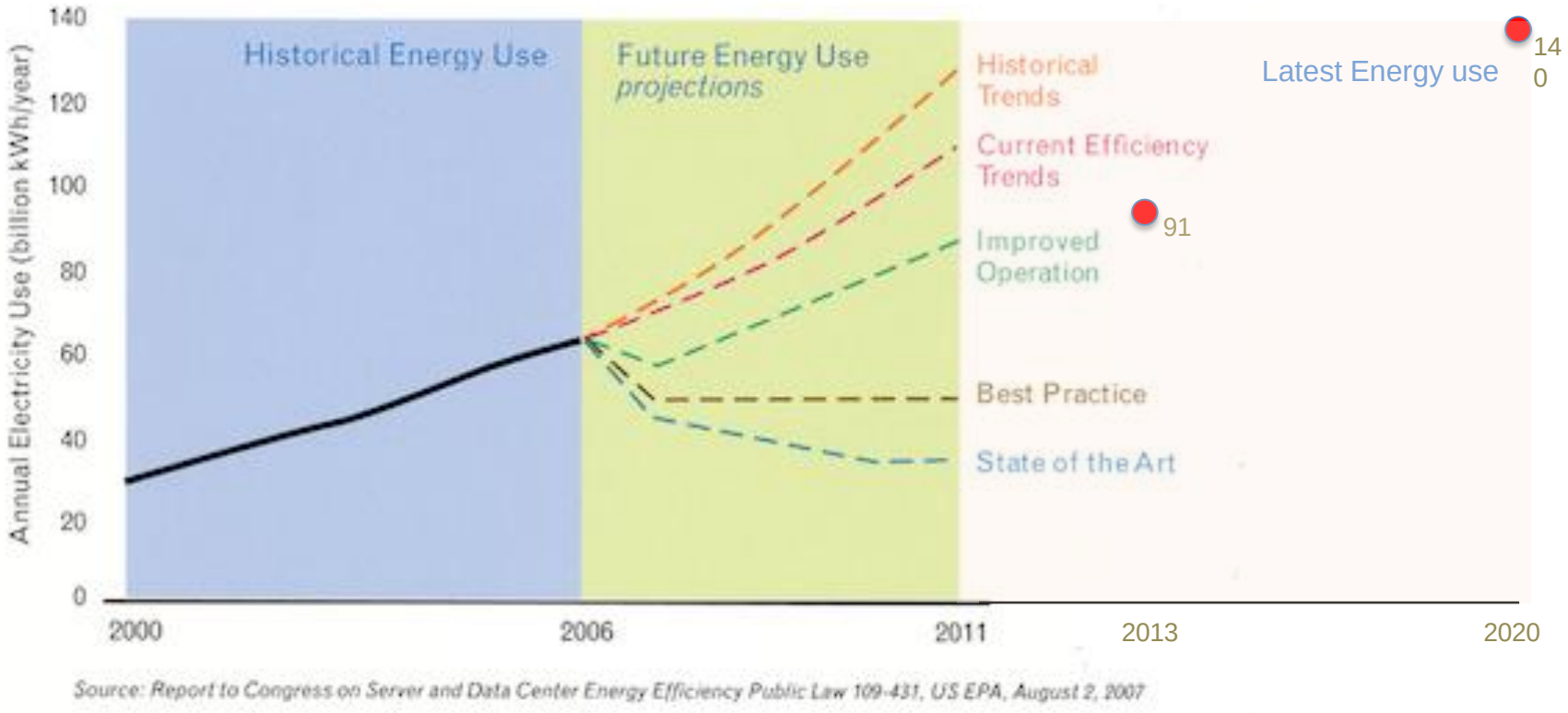


WHAT DOES THIS HAVE TO DO WITH DATA CENTERS OR LABS? THE BAD NEWS AND WHAT WE CAN DO ABOUT IT.

Data Centers are still using too much power

- Data centers can waste 90 percent or more of the electricity they pull off the grid.
- Worldwide, there are now more than 30,000,000 data centers that use about 30 billion watts of electricity; ≈30 nuclear power plants.
- If just half of the savings potential from adopting energy efficiency best practices were realized, America's data centers could slash their electricity consumption by as much as 40 percent. In 2014, this represents a savings of $3.8 billion and 39 billion kilowatt-hours, equivalent to the annual electricity consumption of all the households in the state of Michigan. *Source: E.R.* Masanet et al., "Estimating the Energy Use and Efficiency Potential of U.S. Data Centers," Proceedings of the IEEE 99, No. 8 (August 2011): 1440-1453.

What Difference Will it Make?



"If we do nothing to change our data center consumption, 10 more power plants need to be built (over the next four years) to the tune of 2 billion to 6 billion each and their cost is ultimately going to get passed on to IT through increased utility bills." - Ken Brill, *Forbes Magazine*

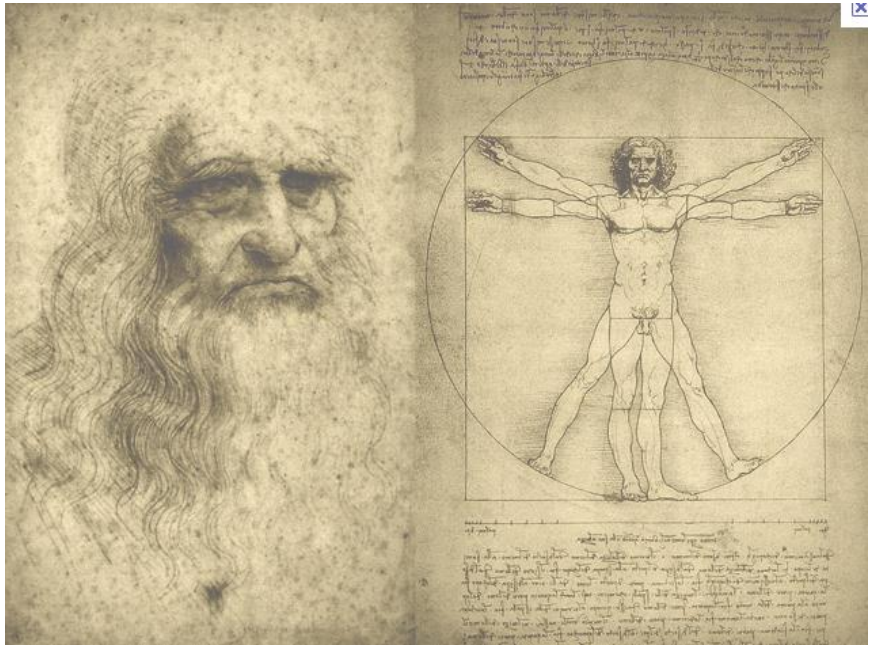
*Google used more than **3gWh** in 2016, a* 12-fold over the last four years. Your smart phone total power impact is now greater than a refrigerator.

So what was NSIDC doing about this with it's data center?

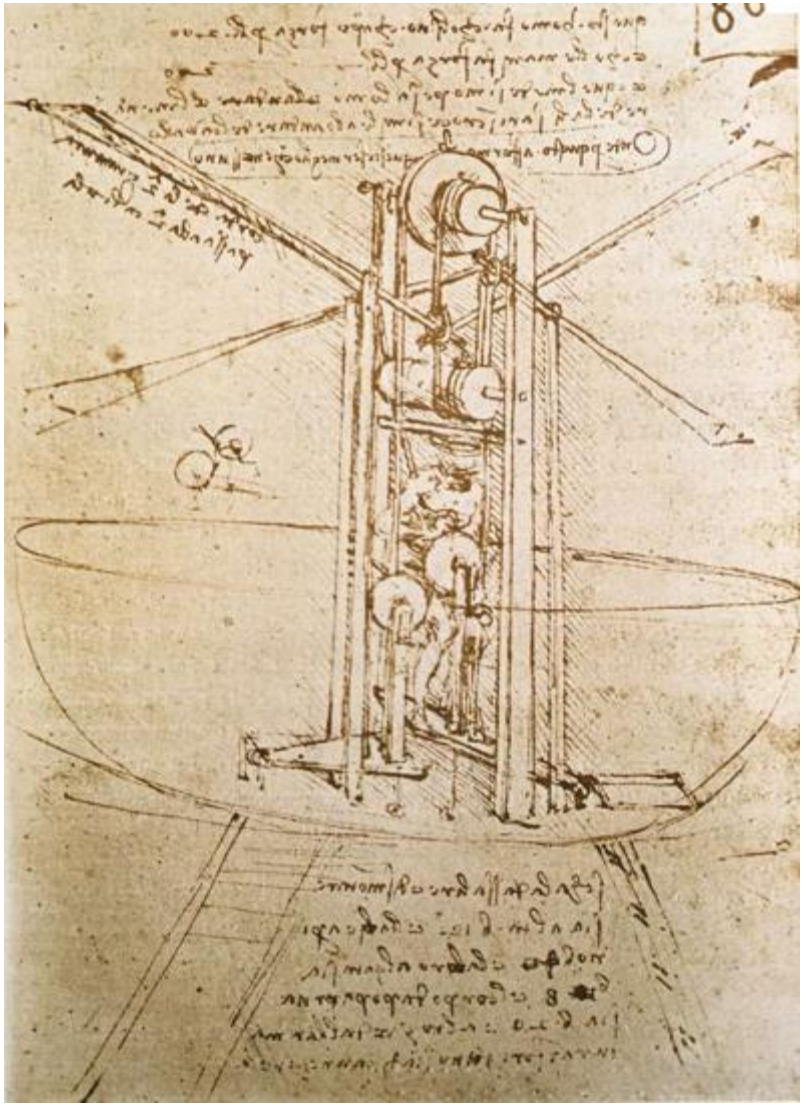
- The NSIDC is a NASA-essential services facility and a Polar archive serving NSF and NOAA programs and scientists
- We are a climate research center
- The NSIDC manages, processes, archives and distributes petabytes of polar orbiting satellite data worldwide
- NSIDC's data center facility at the University of Colorado, Boulder *was* an industry average efficiency of PUE 2.0

Search for Out-of-the-Box Design

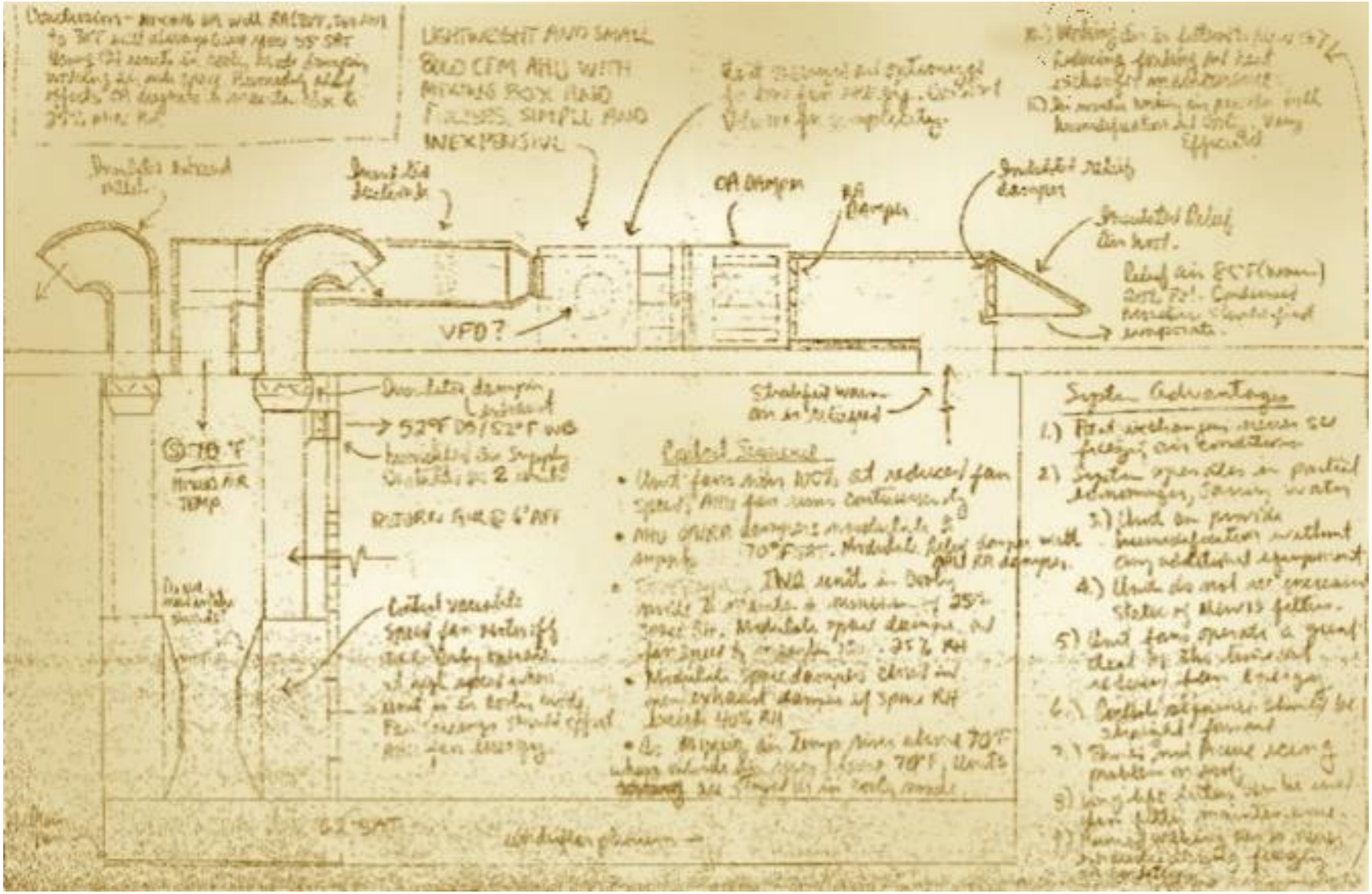
We needed someone to work within our specs and budget.
We needed a miracle!



Leonardo da Vinci



RMH Conceptual Design

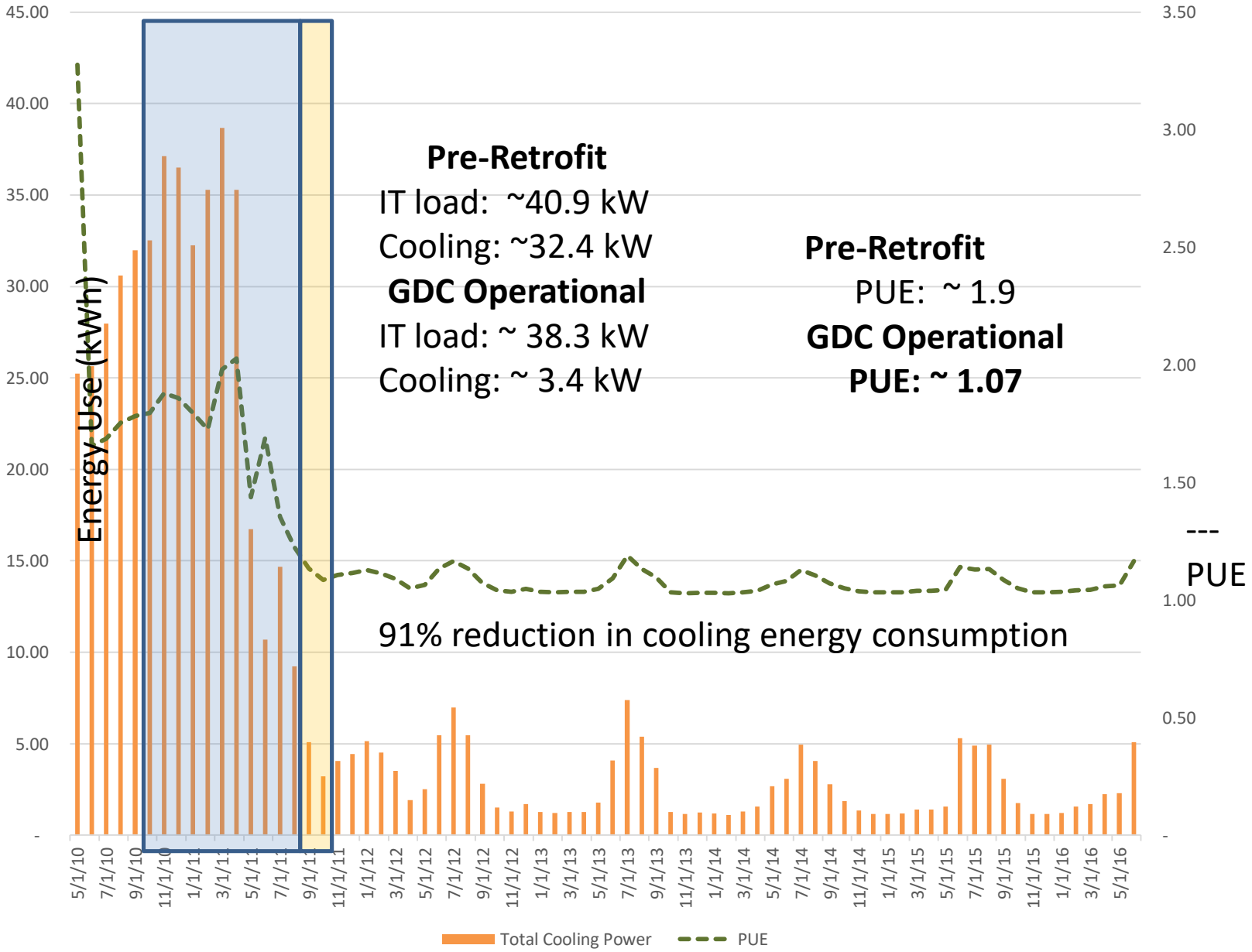


System Advantages

- Cost-effective components
  - Single air handling unit is simple, inexpensive
  - Fan, filters and dampers sized for low pressure drop, low fan energy use
- Indirect Evaporative units are expandable and modular
- Precise control of temperature and humidity
- No compressors used in design = greater reliability
- Energy savings guaranteed; no equipment to run except fans; 24/7 operation; lower maintenance costs
- Connected HP for system is so low that it can be run from UPS (fan is always run from UPS).
- **Low energy use > 90% less than existing system**

Evaporative Chiller Product Air Side with Working Air Humidification Dampers

NSIDC Green Data Center Energy Use



The Ugly Truth: Renewable Energy Sources Could be Considerably Cleaner

Solar energy requires components which are manufactured using lots of traditional coal energy. The wind power industry produces a great deal of toxic waste. Mining rare earth minerals, which are required wind and some solar energy is a dirty business.

The old adage about how you don't want to see how sausage is made applies to renewable energy as well. China is now opening the largest rare earth mine in Greenland. There are environmental costs for those rare earth minerals.

Rare earth mining in China and Mongolia

All Forms of Energy Production have impacts on the Environment

- Coal: The worst by far in terms of emissions, water use and impact
- Nuclear: Can we prevent another Fukushima disaster?
- Natural Gas: A fossil fuel but much better than coal
- Hydroelectric: Massively alters the landscape & not available everywhere
- Solar: Requires massive energy to produce the panels, requires storage (now cheaper than coal)
- Wind: Uses lots of rare earths, impacts on birds, requires storage
- Geothermal: Probably the least damaging but not available everywhere

All our existing technologies will have some negative impacts…the key is to select those with low impacts, high availability that can buy us time, and the time is short. Energy Efficiency is critical.

Over the next decade, data center power and cooling technologies will undergo major transformations. Next-generation data centers have an opportunity to improve energy efficiency through various approaches, including:

- Continued shift toward virtualization
- More efficient power distribution
- Mixtures of cooling technologies, such as free cooling, evaporative cooling, liquid and no cooling
- More appropriate data center site selection
- Much warmer data center temperatures
- New cooling improvements, such as variable-speed motors
- More realistic data center power usage targets
- **Demand** hardware that can run at 150^{o} F

Conclusion:

- *All* forms of energy (fossil, solar, wind) have a negative environmental cost (some are obviously better than other)
- *Only* energy efficiency lowers both costs and environmental impacts
- *Don't* let them tell you it can't be done. The creative for things you can do for efficiency will make a difference

David Gallaher, Senior Scientist,
National Snow and Ice Data Center
david.gallaher@colorado.edu
david.gallaher@orbitalmicro.com